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AIR QUALITY MANAGEMENT PLAN
1988 REVISION

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APPENDIX IV-C
TIER III CONTROL STRATEGIES
SOLVENT FUTURE

SOUTH COAST
AIR QUALITY MANAGEMENT DISTRICT

MAY 1988

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Appendix IV-C

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LONG RANGE SOLVENT REPORT

Executive Summary

Chapter I

This appendix presents viable alternatives to the continued use of photochemically reactive organic solvent bases in coating and solvent cleaning operations, as well as consumer products. Substantial reductions are required for reactive organic gas (ROG) emissions, identified as primary precursors to the formation of ozone, as the South Coast Air Basin is not in attainment of the federal and state ozone standards. The primary objective of this appendix is to identify the potential ROG reductions possible from the minimization or total elimination of reactive organic compounds in the solvent use emission categories.

Chapter II

This section presents current and future emissions of reactive organic gases from solvent use in stationary sources. The emissions are identified relative to the formulations and/or processes associated with coating, solvent use , and consumer product use in the South Coast Air Basin. ROG emissions from these processes totalled about 382 tons per day in 1985. These emissions are projected to increase to about 470 tons per day by the year 2007, showing an emission increase of about 26 percent.

Chapter III

The long range control approaches discussed herein are aimed at bringing the basin into attainment with the ozone standards by the year 2007. The basic strategy for reducing emission of ROG's from the solvent use category is to restrict the photochemically reactive components in coatings, solvents, and consumer products, and to reduce ROG emissions during the application or use of the aforementioned products. This may be achieved through the use of alternative non-solvent based methods or products, or replacement of reactive solvent-bases with less photochemically reactive exempt or low-VOC (volatile organic content) compounds.

A number of the proposed control measures may not be currently widely applicable for the control of reactive organic gases from the solvent use source category. Further technical development by the industry, or administrative development by the District may be required before the Tier III control measures can be commercialized and/or required for use at specific facilities.

Chapter IV

The strategic plan proposed is based on the complete implementation of one or more of four control approaches to eliminate ROG emissions in the South Coast Air Basin. The first control approach is based on the adoption of alternative non-solvent based methods or processes. The second control approach requires reformulation with exempt solvent compounds, to be used in conjunction with add-on control devices and improved operating practices. The third control approach also calls for reformulation. Products or processes unable to adopt alternative methods, or utilize exempt solvent reformulations can then use products formulated with low-VOC compounds, also in conjunction with add-on controls and improved operating practices. The final control option is banning of any products or processes unable to comply with alternative products or processes, or reformulated products. Complete implementation of one or more of the four control strategies can reduce Basin ROG emissions by as much as 99 to 100 percent in the year 2007, or about 464 to 470 tons per day.

An assessment of actions required to facilitate implementation of the

strategic plan is included after plan presentation, and is followed by an analysis of the environmental, economic, and energy consumption impacts of the plan.

Chapter V

The overall goal of the Tier III solvent control strategies to drastically reduce or eliminate ROG emissions in the South Coast Air Basin can be achieved through full implementation of the control techniques discussed in Chapter III. Further refinement of the control techniques over the next 10 to 20 years and incorporation of these measures into the Rules and Regulations of the South Coast Air Quality Management District can act to bring the Basin into attainment with federal and state ozone standards by the year 2007.

CHAPTER 1

INTRODUCTION

CHAPTER I

INTRODUCTION

BACKGROUND

Because the South Coast Air Basin is in exceedance of the federal, as well as the state ozone standard, further reductions in emissions of reactive organic gases (ROG), must be achieved. Emissions from solvent use and coating processes comprise approximately 67 percent of all stationary source ROG emissions in the South Coast Air Basin, for the year 1985, and as such, have been targeted for further control.

Organic solvents are used as cleaning agents for degreasing, in surface coatings to reduce viscosity and act as carriers, and in a wide variety of other industrial, commercial and domestic applications. The escape of evaporative solvent emissions during these operations provides precursors for the formation of ozone in combination with oxides of nitrogen in presence of sunlight. The South Coast Air Basin has the most serious air quality problem in the nation, with monitored ozone levels reaching as high as three times the national ambient air quality standard set to protect public health. Mitigation efforts for this severe air quality problem can be greatly enhanced by the minimization or elimination of reactive organic gas emissions in the South Coast Air Basin.

Current District regulations to reduce ROG emissions in the solvent use and coating category involve limitations on the reactive solvent content of products as well as the establishment of a minimum transfer efficiency requirement for several coating categories. The proposed Tier I and II control measures, while able to achieve significant ROG emission reductions, will not result in eventual compliance with federal and state air quality standards for ozone. Therefore, it becomes necessary to further develop and implement more aggresive control strategies able to achieve the level of

emission reductions necessary to bring the basin into attainment with the ozone standards. Further refinement and advancement of technology introduced in Tier I and II is the basic strategy for Tier III ROG control. However, Tier III pushes for full-scale industry wide implementation in the coating, solvent use and domestic products categories.

While radical departure from existing technology is not required for successful implementation of the long range strategies, a significant research and development effort is required for conversion of products or processes to those with no or extremely low solvent emissions. Development of compliant coatings in the wood furniture and products, and plastic coating categories will require significant advances in formulation technology. Reformulation of solvent and oil-based architectural coatings and aerosol and non-aerosol domestic products will also require significant developmental efforts. The fact that the Tier III control measures are based on further technical advancement of existing technology for industry wide implementation and do not require the development of totally new or unproven control concepts, as in several other emission categories, will allow for their expedient adoption by 2007.

OBJECTIVES

The primary objective of this study is to identify the potential ROG reductions possible from the minimization or total elimination of reactive organic solvents in coating processes, direct solvent application, and consumer products. The ultimate goal is to achieve substantial ROG reduction without compromising the quality of the product or the economic feasibility of production operations. In order to fully resolve these issues and assess their potential impact on the air basin, the following objectives were addressed:

(1) To identify ROG reduction measures beyond the existing rules and proposed Tier I and II control measures;

(2) To determine the technological status and advancements required to successfully implement the proposed reduction measures;

(3) To estimate the emission reduction potentials for the control measures as applied to specific source categories.

(4) To propose a strategic plan for solvent use capable of reducing ROG emissions to a level that will bring the South Coast Air Quality Management District into attainment with federal and state air quality standards for ozone by the year 2007;

(5) To identify and evaluate potential impacts of the implementation of the strategic plans;

(6) To recommend implementation actions.

STUDY APPROACH

This study is composed of a technical review and strategic application of long range control measures applicable to the solvent and coating use source categories. The control measures will serve to minimize or eliminate reactive solvent emissions in the South Coast Air Basin and are to be fully implemented by the year 2007.

The study was based on the following assumptions:

(1) Because of data and projection uncertainties, the study assumes no difference between year 2007 and year 2010 projection data (i.e., population, emission inventory). It is also conservative to use year 2010 data in place of year 2007.

(2) A number of the known technological applications are suitable for transfer to other source categories for implementation as long range control measures.

(3) The Tier III control strategy is technology forcing and is based on the premise that this will spur the development and refinement of nonreactive solvent formulations and alternative coating technologies.

(4) The estimated long range reduction potentials for the solvent and coating categories assume the absence of the application of other control strategies.

METHODS

This section outlines the study methodology and the steps taken to accomplish the objectives as previously.

(1) To identify the major types of solvent and coating operations within the District to aid in the determination of the scope of the project.

(2) To identify and evaluate currently available control technologies involving reformulation and alternative processes or modifications which may be further developed as Tier III measures for broader applications by multi-source categories.

(3) To identify and evaluate alternative formulations and coating technologies which offer substantial ROG reductions and will be technologically feasible by the year 2007.

(4) To propose a basin-wide strategic plan in relation to air pollution control based on findings (1) through (3).

(5) To recommend further study, research and implementation activities by the District.

CHAPTER 2

EMISSIONS INVENTORY ANALYSIS

CHAPTER II

EMISSIONS INVENTORY ANALYSIS

The ROG emission inventory for the South Coast Air Basin is comprised of mobile, stationary, and other sources. The stationary source category is further broken down into solvent use and process fugitive emissions. This study will examine the emissions from stationary sources in the solvent use category which include coating processes, direct solvent application, and consumer products.

The following sections discuss the emissions relative to the formulations and/or processes associated with coating, solvent, and consumer product use in the South Coast Air Basin.

CURRENT AND FUTURE EMISSIONS OF REACTIVE ORGANIC GASES

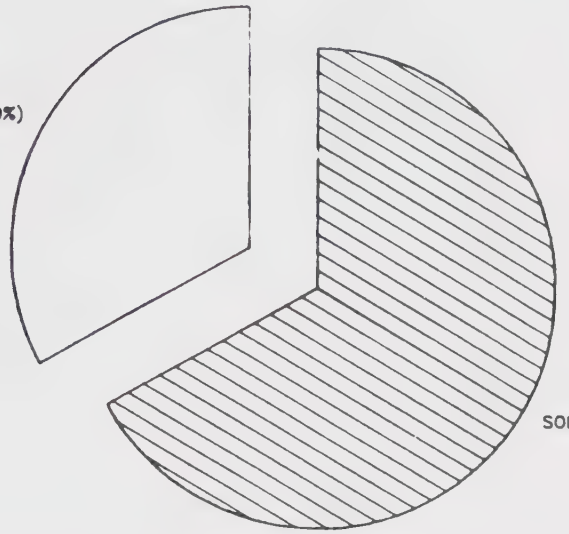
Table 2-1 lists ROG emissions totaling about 382 tons per day, from solvent use by source categories for the year 1985. These emissions are projected to increase to about 470 tons per day by the year 2007, showing an emission increase of about 26 percent. Figure 2-1 shows 2007 ROG emissions from the solvent use categories comprising about 67 percent of Basin stationary ROG sources.

TABLE 2-1
ROG EMISSIONS FROM SOLVENT USE IN THE SOUTH COAST AIR BASIN

SOURCE CATEGORY	EMISSIONS 1985 (TONS/DAY)	EMISSIONS 2007 (TONS/DAY)	% INCREASE ABOVE BASELINE
Direct Solvent Application			
Industrial Solvent Use	20	22	10%
Solvent Cleaning & Degreasing	23	36	57%
Dry Cleaning	16	26	62%
Asphalt Paving	3	5.	67%
Subtotal	62	89	44%
Coating			
Architectural Coating	64	50	-22%
Other Surface Coating	154	194	26%
Graphic Arts Printing	5	4	-20%
Subtotal	223	248	11%
Consumer Products	94	129	37%
Other	3	4	33%
Total	382 ton/day	470 tons/day	28% avg increase

Figure 2–1 2007 Stationary ROG Emissions versus

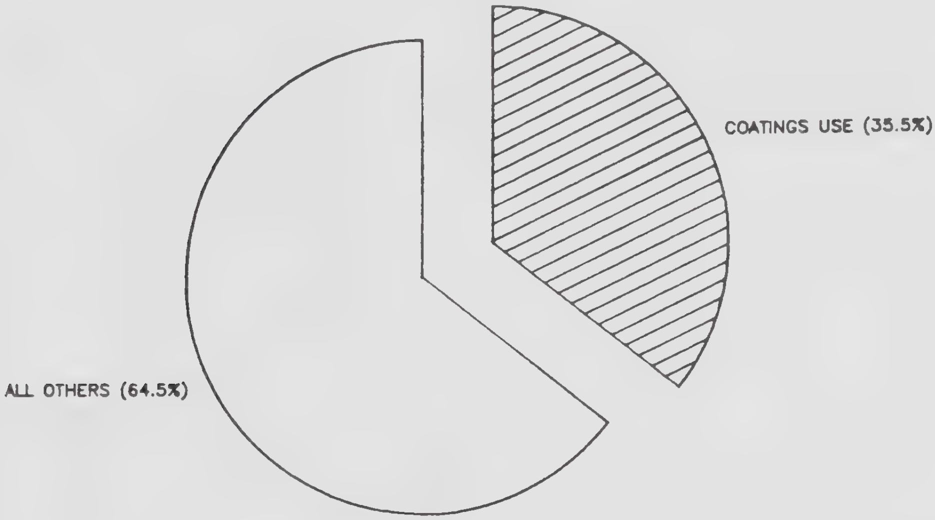
Stationary Solvent Use ROG Emissions



Coatings

Reactive solvent-based coatings are applied to a wide variety of substrates including metal, plastic, wood, rubber, glass and paper. Reactive solvent content may vary from less than 10 percent by volume in high solids coatings, to as high as 85 percent in acrylic lacquers. Fugitive evaporative emissions can occur during coating application, drying and/or curing, and cleaning of application equipment or work areas. ROG emissions from architectural coating use in 1985 show a decrease of about 22 percent by 2007, declining from about 64 tons per day to 50 tons per day. This decline is due to water borne formulations holding the market share among architectural coating formulations. Other surface coating categories in combination show a 26 percent increase from 1985 baseline emissions, rising from 154 tons per day to 194 tons per day in 2007. This increase may be due in part to the increasing population and economic growth in the South Coast Air Basin, as well as the reluctance of finishers to switch to alternative formulations or application processes. ROG emissions from coatings comprise approximately 36 percent of all stationary ROG sources in the Basin as can be seen in Figure 2-2.

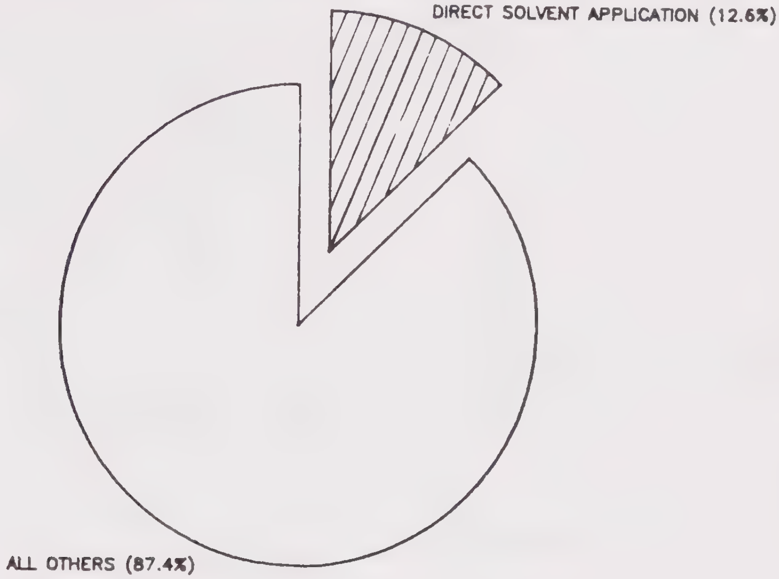
Figure 2-2 2007 Stationary ROG Emissions versus
ROG Emissions from Coatings Use



Solvents

There are a variety of source categories with the potential for substantial emission of reactive organic gases from solvent use. Solvents are employed mainly as cleaning or degreasing agents, and in the pretreatment of surfaces before coating or other industrial processes. Fugitive evaporative emissions may enter the atmosphere from solvent degreasers, open air solvent cleaning, improper storage or handling of solvent cleaners and/or supplies (e.g., solvent-laden rags, etc.), as well as malfunctioning or improperly operated solvent recovery devices. Table 2-1 shows ROG emissions from direct solvent application for the year 2007 projected at 89 tons per day, showing an average increase of about 44 percent over 1985 baseline emission levels. Direct solvent application emissions are estimated to comprise about 13 percent of the total Basin ROG emissions in the year 2007, as can be seen in Figure 2-3.

Figure 2–3 2007 Stationary ROG Emissions versus
ROG Emissions from Direct Solvent Application

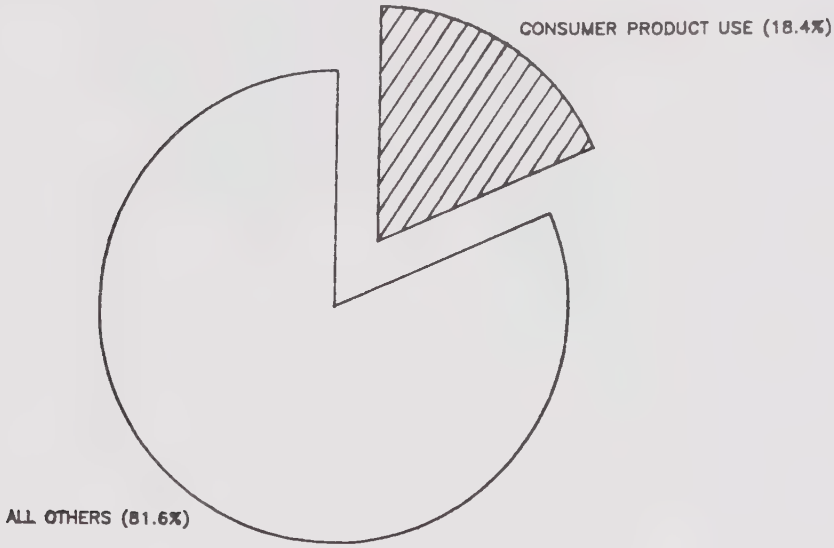


Consumer Products

The consumer products category is comprised of products containing reactive organic solvents which are used as propellants and/or carriers in aerosol spray products, including paints, cleaning solutions, insecticides, and personal care products such as deodorant and hairspray. Many of these products are also used in non-aerosol formulations which contain equally reactive solvent bases. Fugitive emissions are released to the atmosphere upon dispensing, application, and storage of the products. ROG emissions from the consumer products category are projected to increase from about 94 tons per day in 1985 to 129 tons per day in the year 2007, an increase of approximately 37 percent. Again, this increase is due to the rapid population and economic growth expected in the Basin in the next 20 years. Consumer product ROG emissions can be seen in Figure 2-4 as being approximately 18 percent of all stationary ROG emissions in the basin for the year 2007.

Figure 2–4 2007 Stationary ROG Emissions versus

ROG Emissions from Consumer Product Use



CHAPTER 3

CONTROL STRATEGIES

Operating Practices
Alternative Methods
Transfer Efficiency
Process Modificiations
Add-on Control Devices
Reformulation
Banning

CHAPTER III

CONTROL STRATEGIES

In order to realize the ROG emission reductions necessary to meet air quality standards by the year 2007, a very stringent control strategy must be applied. The means of the solvent reduction strategy are defined as: (1) minimizing or eliminating the reactive organic contents in products; (2) minimizing the use of products which continue to contain reactive organic solvents; (3) minimizing uncontrolled emissions from coating application processes; and (4) maximizing the capture or recovery of ROG emissions.

Control Elements

The control elements applied to achieve the needed reductions in Tier III are in many cases technology forcing. However, it is presumed that the impending implementation of the long range strategy will act to motivate formulators as well as end users industry wide to develop and completely incorporate improved operating practices, alternative cleaning methods, process modifications, add-on controls, reformulated products, improved transfer efficiency applications, and banning, if necessary, into solvent use operations. The following section presents a brief description of the control elements to be applied to the solvent use categories for Tier III ROG reductions in order of the projected degree of difficulty for development and implementation.

I. Operating Practices

A wide range of operating practices can be utilized in processes which use solvent-based products for cleaning and/or coating to eliminate fugitive

evaporative solvent emissions. Improved storage and handling of solvents and cleaning supplies (e.g. solvent-laden rags) in order to facilitate capture or prevent the escape of evaporative fugitive emissions will aid in the elimination of ROG emissions. In addition, the use of equipment inspection and maintenance programs, especially on coating lines, can reduce the amount of extensive solvent cleaning required. This control element alone can not achieve the required ROG emission reductions, and as such, throughout the remainder of this study, will be incorporated into the use of any exempt or low-solvent reformulations. Outreach and educational programs aimed at business owners and operators can be developed and sponsored by the District and other state or local agencies. The program would stress the use of cost effective alternatives to solvent use in normal operating practices, and provide guidance to achieve compliance with the solvent use regulations. The outreach/educational program will be introduced in Tier I and is to continue throughout implementation of Tier II and III strategies.

II. Alternative Methods

Alternative methods employing non-solvent based processes or products are currently available for application to a number of parts coating and cleaning operations, as well as the consumer products category. Alternative methods applicable to the coating category include the use of powder , aqueous powder, or radiation curable coatings. These types of coating applications require no solvent clean-up, thus, ROG emissions are further reduced. Several non-solvent based alternatives to solvent-based cleaning can also eliminate ROG emissions. These methods include: 1) peel coatings to be used in place of oil as a protective coat for metal parts, thus requiring no solvent degreasing prior to use of the part; 2)the use of water based cleaning solutions which may contain caustic or detergent components and could be used as for spray or dip part cleaning; 3) the use of non solvent based paint stripping methods such as water-based strippers, abrasive blasting, cryogenic stripping which utilizes liquid nitrogen in combination with abrasive blasting, thermal stripping, and molten salt bath stripping. Alternative methods in the consumer products category can be developed to replace photochemically reactive aerosol propellants with non solvent propellant mechanisms such as the self generating carbon dioxide spray or the use of pumps, sprays, and

squeeze bottles. Tier III strategy involves maximum penetration of alternative methods or processes throughout the coating and solvent use industries.

III. Transfer Efficiency

Transfer efficiency is defined as the ratio of the weight or volume of coating solids adhering to an object to the total weight or volume respectively, of coating solids used in the process, expressed as a percentage between the volume of paint deposited on product and the total amount applied. The use of more efficient application methods in all coating processes such as higher transfer efficiency sprayguns, or automated robotic spraying lines can reduce ROG emissions by lowering coating material consumption as well as reducing the need for clean-up solvents. As the coating application becomes more efficient, finishers will benefit financially as material consumption costs, waste solvent disposal costs, product rejects, and coating line downtime decrease.

IV. Process Modifications

Process modifications can be employed to reduce ROG emissions from clean-up or surface coating operations. They may involve modification of the existing solvent-based operation to ensure more efficient coating or clean-up operations, greater capture of contaminated airflow and reduction of the volume of air treated or, may involve a switch of a portion of the operation to a non-reactive or non-solvent based technology. Process modifications can be employed in conjunction with add-on controls to achieve more cost effective control system operation. One successful example currently in use employs microprocessor controls in coating drying ovens to reduce ventilation air flow so that a higher percentage of the LEL (lower explosive limit) or a greater VOC concentration can be reached before the ventilation air enters the incinerator. With a decrease in the amount of air flow and an increase in VOC concentration into the incinerator, the need for large volumes of process ventilation airflow is decreased, as well as the energy

demands of the add-on system. Further technical developments in this area can lead to more widespread application resulting in increased ROG emission reductions and reduced process energy consumption.

V. Add-on Control Devices

Add-on control devices can be employed in a broader range of operations in which solvent based products continue to be used. Control devices such as incinerators and carbon adsorption systems are used to treat solvent-laden process waste gas streams and have achieved high efficiencies of destruction or capture. Incineration or afterburning involves the destruction of a process waste gas stream through oxidation, in which the volatile portion of the waste gas stream reacts at high temperatures with oxygen to form carbon dioxide and water. The waste heat may then be used as combustion air for reuse in the incinerator or passed through a heat recovery system where it may be used to heat water. Incineration units with high efficiency and low fuel consumption are currently on the market and further technical development can make these units available for processes with low waste gas volumes.

Carbon adsorption units are also very efficient at controlling ROG emissions from VOC-laden process waste gas streams. The carbon adsorption system works by passing the waste gas stream through a bed of activated carbon where the organic molecules make contact and adhere, and the clean gas is able to exit. The solvent molecules are desorbed by injecting steam into the carbon bed to break the attractive forces. The recovered solvent is then available for reuse in its original form or as a lower grade product, or collected for disposal.

Carbon adsorption units may also be used in conjunction with afterburning units. The solvent-laden gas stream is passed through a carbon adsorption unit where the organic molecules are concentrated and the airflow reduced before the waste stream enters the incineration chamber. A higher degree of operational efficiency is achieved using the two systems in combination in cases where large ventilation airflow with low or varying concentrations of ROG's are present. Development of such systems to handle low waste gas flow volumes at less prohibitive costs can make this ROG control technique more widely available.

The use of wet scrubbers in combination with closed loop solvent recovery systems have achieved successful ROG capture in a number of industrial solvent use industries, such as electronic component manufacturing. These control systems are able to capture ROG's by passing the gas stream upward through a packed column as water or other scrubbing solutions are passed downward, capturing and removing the volatile contaminants in the waste gas stream, and allowing the clean exhaust to exit. The solution and the absorbed VOC's are then passed through a heat exchanger and stripper column where the volatile portion is stripped from the absorbent liquid. The volatile organic vapors then enter a condenser where they are converted to a liquid state, and stored in collection tanks for subsequent return to the process or reclamation. The absorbent liquid is regenerated and returned to the scrubber column for further use. ROG removal efficiency can be greater than 99 percent (Ceilcote, 1987). Further study into the application of wet scrubber systems for ROG control may make this technology available to other solvent use facilities.

VI. Reformulation

Reformulation shall be defined for this report as replacement of photochemically reactive solvent bases with lower content by volume or less reactive exempt solvents or with water bases. Industry wide reformulation will require a great deal of research and development by product manufacturers as they strive to formulate low or nonsolvent products while maintaining performance characteristics comparable to their former solvent-based counterparts. The use of exempt or less photochemically reactive solvents such as 1,1,1 trichloroethane and methylene chloride offer lower ROG emissions, but some uncertainty remains regarding the toxic effects of these solvents. Water-based products such as architectural coatings have been successfully developed and hold the leading share for sales of formulations in that coating category. Exempt or low solvent reformulation in combination with add-on control devices offers the potential for significantly reduced ROG emissions from the solvent use source categories. Crossover of these successful reduced or non-reactive solvent formulations into other coating categories where they are presently, or in the short-term, unavailable is slated for Tier III implementation.

VII. Banning

In the event that products or processes are unable to switch to alternative non-solvent based technology, or use products reformulated with exempt or low VOC solvent bases, these products or processes will then be banned from use in the South Coast Air Basin.

POTENTIAL APPLICATION BY SOURCE CATEGORIES

The control elements described are proposed for application to the coating, direct solvent application, and consumer product categories. The following sections introduce the potential control elements applicable to each of these source categories, and is followed by an application of the proposed control measures and an estimated emission reduction for each source within the three categories. The ROG reduction potential is based on year 2007 emission projections and complete application of one or more of four control approaches to all sources within the coating and solvent use categories. The first control approach examines the use of alternative methods and processes for eliminating reactive solvent emissions. The second approach concentrates on the reformulation of products with non-reactive exempt solvents to be used in conjunction with add-on controls. The third control approach is based on reformulation of reactive solvent-based products with low reactive solvent content by volume, also to be used in conjunction with add-on control devices. The final control approach to be analyzed considers the emission reductions achievable through the elimination or banning of all reactive solvent-based products or processes remaining after complete implementation of the three previous control approaches.

Coatings

Coatings are applied to surfaces for functional purposes, such as protection from environmental elements; to impart characteristics to a surface that are not inherently present, or for decorative purposes. Coating formulations often contain a high amount of volatile solvents which are used as carriers for film forming binders, pigments, powders and adhesives. The type and

amount of solvent in a coating formulation may vary depending on the type of coating that is required, drying speed, type of substrate to be coated, and the properties of the solvent. Coating formulations must be evaluated for use, taking into consideration the substrate to be coated and the method of application. The solvent content in coating formulations may vary from as high as 85 percent in acrylic lacquers to the absence of solvents in powder and some water-based coatings.

I. OPERATING PRACTICES

Several operating practices can be utilized to reduce fugitive solvent emissions in coating processes. The measures are, for the most part, related to coating material handling and storage techniques. Extensive use of restricted areas for mixing or storage of solvent-based coatings, such as in areas ducted to add-on control devices, can reduce fugitive ROG emissions. The development of inspection and maintenance programs for coating lines and equipment can result in less solvent clean-up being required, thus less ROG's emitted. Training programs for coating operations employees aimed at efficient use of application equipment, and proper storage and handling of coating materials could be employed by the facilities to facilitate elimination of fugitive ROG emissions.

II. ALTERNATIVE COATING METHODS

Alternate coating technologies may employ methods which are in their infancy as far as industry-wide implementation or technological development, but which, in the face of continued mandated lower VOC limits, increasingly stringent hazardous waste disposal requirements and escalating operating costs, offer the potential for long range ROG emission reductions. These reductions may be achieved through the use of alternative non-solvent coating methods, such as powder coating or radiation-curable coating. Alternative non-solvent based coating methods require no solvent clean-up, and as such, result in emission reductions in the solvent clean-up category as well.

Powder Coatings

Powder coatings are really just solid paint supplied in a dry, free-flowing powder form. Each particle is a fully formulated paint composed of a solid film-forming resin, pigments, and additives which melt and flow at elevated temperatures to produce a smooth surface coating film. The finish is of high quality, and has excellent mechanical properties such as corrosion, impact, and abrasion resistance. The coating is applied most efficiently using electrostatic attraction, and product utilization rates approaching 98 percent can be achieved using powder reclamation systems. Economic savings including reduced energy costs, savings in labor and maintenance costs, and extremely low waste disposal costs have been well documented by users in both the United States and Europe. Powder coating application is used extensively in the automobile, large appliance, and heavy equipment coating industries (Gribble, 1987).

Because of its 100 percent solids nature, powder coating releases no solvent to the air and is virtually pollution free. Future advances in technology should be able to produce even thinner coatings with greater impact resistance, as well as formulations of powder coatings that may be applied at low temperatures to plastic and wood substrates. The use of powder coating systems is expected to increase, and offers a viable alternative to conventional solvent-borne coatings (Bocchi, 1986). The opportunity for technology crossover into other coating categories appears promising, and will require further research and development for application to specific coating operations.

Aqueous powder suspensions are a variation of dry powder coating, and involve the suspension of the powder in an aqueous solution. However, unlike water-borne coatings, this type of coating contains no solvent and therefore, results in no ROG emissions. These suspensions can be applied by conventional spray, airless spray, dip coating, electrostatic spray and roll coating. As in powder coating, the paint particles melt and flow at elevated temperatures to produce a smooth surface coating film. This type of coating line is in its developmental stages and has not, as yet, experienced widespread use. However, it could be incorporated into industrial metal product coating lines in the future.

Radiation Curable Coatings

In radiation-cured coating applications, radiant energy in the form of infrared or ultraviolet light or a high energy electron beam is used to polymeric or cure the low molecular weight components of specially formulated coatings. These types of coatings do not require direct thermal expenditure of energy where a reactive solvent is driven off and released to the atmosphere. Radiation curable coatings are 100 percent reactive, due to the absence of volatile solvent losses, and the fact that the liquid coating applied to the substrate is totally converted into a solid cross-linked film. This results in a virtual elimination of ROG emissions. In the curing process, electrical or light energy is absorbed only by the coating and is not wasted in heating the substrate below as occurs in conventional thermally cured coatings. Radiation-curable coatings offer additional advantages over solvent-borne coatings, including a rapid low temperature curing rate, increased production, savings in energy costs and space of application equipment, and the creation of a market for high quality specialized products (EPRI, 1986).

Disadvantages associated with radiation-curable coatings involve higher cost than conventional coatings and problems related to shrinkage upon curing. Most radiation-curable coatings have a shrinkage rate of from four to seven percent, which is attributable to the shortening of molecular bonds. This results in a density increase in the surface film which in turn causes shrinking, sometimes curling the stock to which it has been applied or stressing the coating which may lead to its brittleness or cracking. Upon aging, certain volatile film components also may be lost, resulting in further film shrinkage or cracking caused by stresses developed in the film. Another problem associated with these types of coating systems is adhesion failure resulting from rapid film formation and shrinkage, which does not allow for gradual relaxation of the stresses set up during curing (Lawson, 1986).

As technical issues are resolved, future developments for radiation curing seem limitless. A number of commercial operating lines are currently in place, while adaptation of radiation-curable coating in other operations is represented by pilot or experimental lines. The demand for radiation curable materials is expected to grow in the future. Many producers will use the rapid, positive curing of UV and EB to achieve the product quality and uniformity required to command a better price and/or increased market share (Lawson, 1986).

Infrared (IR) coating systems involve the use of electric lamps emitting short, medium, or long wave infrared radiation toward the material that is processed as it passes through a drying area or oven to thermally drive off solvents or water from an ink or coating system. This is done through oxidation in the air or through other forms of thermally activated chemical reaction processes (EPRI, 1986). This process is used mainly in the curing of thin layers of inks and clear overcoats applied in graphic arts, printing, plastic and metal coating, and adhesive industries.

Ultraviolet (UV) coating systems normally use mercury vapor lamps for initiating reactions of UV responsive materials and is the most widely used of the radiation curing methods. Ultraviolet curable coatings are high in solids and offer a fast low temperature cure without blistering and with a long coating pot life. They have been used extensively in wood coating for particle board manufacture; metal coating for wire, rod, and metal tubing; film and paper coating; and as clear protective topcoats for vinyl flooring, upholstery and wall coverings (Lawson, 1986). Increased market penetration is predicted for this type of radiation curable coating, as product suitability and performance requirements are advanced.

Electron beam (EB) curing systems employ the use of high energy, concentrated electron beams to initiate curing. This type of curing allows for greater penetration of opaque films, such as fillers and colored topcoats, at very high solids and at high production rates. EB units are used mainly for large volume production outputs, where their high capital costs (approximately $300,000 in 1986 dollars) can be offset. Growth is shown for this curing method in the areas of paper, film and foil converting; magnetic media production, and other fields not readily adaptable to UV curing (Lawson, 1986).

III. PROCESS MODIFICATIONS

Process modifications can be used to aid in the reduction of ROG emissions from painting or coating processes in cases where switching to alternative methods or processes or, using exempt or non-solvent based coatings or more efficient application methods are not feasible. Process modifications may be combined with the use of add-on control devices in order to achieve greater operational effeciency of the emission control system. One successful

example of such a modification involves a system which uses activated carbon fiber for adsorption/desorption of solvents from the paint spray booth exhaust, concentrates the solvents into a much smaller more concentrated flow, and then burns them in a catalytic incinerator achieving ROG emission reductions as high as 95 to 99 percent (Kenson, 1987).

Another successful example of process modifications leading to more efficient ROG destruction involves increasing of the percentage of the LEL (lower explosive limit) of ROG emissions in the drying oven at a metal coating facility. Normally, the solvent concentration in the drying oven is maintained at 5 to 10 percent below LEL, requiring large volumes of ventilation air to remain at this level. However, it was discovered that, through the use of microprocessor controls, the oven ventilation air flow could be decreased while safely increasing ROG concentration to near 50 percent of the LEL. By decreasing the oven air flow, energy demands for curing were lowered, as well as for incineration of the now more concentrated oven exhaust. The facility fitted with the test process modifications achieved destruction efficiencies greater than 99 percent (Darvin, 1984).

Process modifications of this type are very effective for high levels of ROG capture and destruction, and can offer a plausible alternative for increased cost-effectiveness of add-on controls for many coaters who are forced to continue using exempt or reactive solvent-based coatings until alternative products or processes with similar performance characteristics are available.

IV. TRANSFER EFFICIENCY

The use of increased transfer efficiency coating application methods not only may result in ROG emissions reductions as high as 15 to 60 percent (DOHS, 1986), but may also result in financial savings for the finisher as coating efficiency and product acceptability will increase, downtime for equipment clean-up and waste disposal costs will decrease, and energy cost may be lowered as less climatically controlled make-up air is needed in the spray booth. Processes to increase transfer efficiency in combination with the use of low-solvent coatings, such as high solids formulations, can result in an additional emission reduction of 30 to 50 percent. In addition, the use of higher transfer efficiency application methods results in the need for less

solvent clean-up, thus reducing ROG emissions from the clean-up solvent category as well.

A number of the coating methods are previously introduced as Tier I and II control measures. In order to achieve the ROG emission reductions necessary by 2007, the higher transfer efficiency coating techniques are reintroduced for complete industry wide implementation in Tier III.

Spray Coating Applications

Spray coating is currently the most widely used method for paint application. Generally, a spray gun which atomizes the coating by passing it through a small orifice under high pressure compressed air is used. A very turbulent and non-directional spray is created due to high rate of material and/or air passing through the orifice at high pressure (Can Am Systems, 1987). This application method commonly results in over atomization of the coating product, creating fogging, misting and a high degree of overspray, with transfer efficiencies being in the range of 30 to 60 percent (DOHS, 1986). Several improved variations of this method are also used, including airless spray, air assisted airless spray, high volume low pressure spraying, and electrostatic spraying. The characteristics of these methods are summarized below.

> **In airless spraying, the coating agent is forced out of the spray gun** under high pressure and no air is needed for atomization. Less fogging and overspray result and transfer efficiencies may be in the range of 65 to 70 percent (DOHS, 1986).
>
> **In airless air-assisted spray application, the coating agent is forced** out of the gun under high pressure and air is used to help atomize and contain the coating stream. Transfer efficiencies can be in the range of 65 to 80 percent (DOHS, 1986).
>
> **Low pressure high volume spray coating application involves the use** of high volumes of low pressure air to atomize and deliver the coating agent. Because of the ability to handle a large volume of air through the relatively large atomizing air holes on the spray guns used, a laminar air flow with low turbulence is created. This low pressure laminar air flow causes the material to strike perpendicular to the

surface, reducing material bouncing and is also very effective for penetrating into deep recessed areas. This application technique is becoming more widely used and may achieve transfer efficiencies as high as 60 to 80 percent (Can Am Systems, 1987).

Electrostatic spraying involves the positive charging of the paint leaving the gun and the grounding of the object receiving the coating so that an electrical attraction exists between the two. Transfer efficiencies for this process with conventional air spraying can be in the range of 65 to 85 percent, and can be even higher when used in combination with the use of airless , air assisted airless, or high volume low pressure spraying (DOHS, 1986).

Roll and Knife Coating Application

Roll and knife coating are used to coat flat surfaces or continuous flexible sheets such as in coil coating and printing operations. In roll coating the paint is applied to a roller and is transferred to both sides of the object by contact. Knife coating also involves the application of paint by contact. In this process the coating is applied to one side of the coil as it passes beneath the metal blade which serves to spread the coating in an even film thickness onto the coil. Transfer efficiencies for both processes can be in the range of 90 to 98 percent (DOHS, 1986).

Dip and Flow Coating Application

In dip coating the coating to be applied is held in a tank and the object to be coated is lowered into the tank and removed after a specific period of time to drain. Industrial production lines have been successfully dip coating large items such as home appliances and automobile bodies, while achieving transfer efficiencies in the range of 75 to 95 percent (EPA, 1981). This application method may not be feasible where space does not permit installation of dip tanks or cases where coating formulations cannot remain in the tanks for extended periods of time without beginning to cure or releasing hazardous or toxic emissions.

Items that can not be dipped in tanks because of their size or weight, or where dip coating is not economically feasible, are often flow-coated. This application method involves flooding the items with an unatomized shower of coating material, which is followed by draining the excess paint and recirculating it for later use. Transfer efficiencies for this coating method are in the 75 to 95 percent range (EPA, 1981). In both dip and flow coating, problems of uneven thickness of film application, drips and sags have resulted.

Electrocoating

Electrocoating is a variation of dip coating where a water-borne coating is applied to metals by electrically coagulating paint solids on the metal surface. The coated objects are then removed from the tank and rinsed to remove excess coating, and then cured in a drying oven. The process is currently being used for the automotive, marine and office furniture industries. Transfer efficiencies for this coating process are in the range of 90 to 99 percent (DOHS, 1986), and ROG emissions are negligible with the use of a water-based coating. Electrocoating has been viewed by those in the industry as "very good for large runs with no color changes", and as "An emerging technology making vast improvements in quality and economics" (Products Finishing Staff, 1986).

Automation and Robotic Coating Lines

The use of robotics and automation in production painting lines can improve transfer efficiency and productivity; reduce costs and; remove humans from exposure to potentially hazardous compounds, thus improving safety and reducing possible liability. Automobile and appliance manufacturers were among the first to successfully implement robotic technology for production line spray painting, and have opened the door for other industrial coaters (Schmidt, 1984). Coaters of off-road vehicles and farm implements are beginning to apply robotics technology to their finishing operations for the application of high quality coatings at reduced production costs. Aerospace coating operations also offer the potential for technological application, as concern increases regarding worker exposurer to hazardous materials.

Along with an additional increase in transfer efficiency of about ten percent (Can Am Systems, 1987), robotic coating lines can also result in financial savings due to lower product rejection rates and lack of human errors. In addition, energy costs may be reduced because large amounts of make-up air are not required for ventilation of the spray booths, allowing a higher LEL (lower explosive limit) to be reached which could lead to more efficient ROG destruction if add-on controls such as afterburners are used. With the successful implementation of automated painting systems, humans have literally been removed from the paint booths and are now manning computer networking stations where programs can be taught and transferred to robots on the paint production line. The use of automated/robotic painting lines is expected to increase. However, some refinishing industries such as aerospace components, marine vessels and automobiles, in which the products to be coated can vary greatly in size and shape, could find it very difficult and time consuming to set up and use the automated system.

V. ADD-ON CONTROLS

Two types of add-on control devices are normally applied to coating systems, incinerators or carbon adsorption units. Fume incineration or afterburning involves the destruction of a process waste gas stream through oxidation. In this reaction, the volatile portion of the waste gas stream reacts at high temperatures with oxygen to form carbon dioxide and water while releasing heat. The destruction rate for ROG-containing waste streams can be as high as 90 to 99 percent. The main factors affecting the ROG destruction rate are detention time, chamber temperature, and turbulence.

There are two types of incinerators, thermal and catalytic. Thermal incinerators achieve ROG destruction at about 1300 to 1500 ^{O}F, while catalytic incinerators are able to initiate the combustion reaction at lower temperatures in the range of about 700 to 900 ^{O}F (EPA, 1981). Heat from the exhaust stream may be recovered which can be returned as make-up or process air to the incinerator or routed through a heat recovery boiler for air or water heating as needed.

Catalytic incinerators offer several advantages over thermal types such as lower operating temperatures, lower auxiliary fuel needs, and lower construction material costs. However, the catalysts are expensive and can

experience particulate fouling, thermal aging, poisoning, or suppression (EPA, 1981). However, due to the overall economic advantage of catalytic incineration, many existing thermal incinerators are being retrofitted to incorporate a catalyst to reduce operating costs. A simple modification is made to the combustion chamber to install the catalyst and its stainless steel basket. Often the cost of refitting a thermal unit with a catalyst is repaid by fuel savings in less than a year, and the pay-out period decreases as fuel costs increase (Met-Pro Corporation, Systems Division).

Another add-on control device applicable to the coating industry is the carbon adsorption system. In this control technique the process waste gas stream is passed through a bed of activated carbon where the organic molecules make contact and adhere, and the cleaned gas stream is able to exit. When the bed becomes fully impregnated, the waste gas stream is diverted to another adsorption unit and the original unit can be regenerated. This is done by applying steam which acts to break the attractive forces between the captured molecules and the activated carbon bed, releasing water vapor and the solvent so that as high as 98 percent or more (Baron-Blakeslee, 1984) of the captured solvent vapor is available for recovery or disposal.

VI. REFORMULATION

Substantial ROG emission reductions may be realized from the reformulation of paints and coatings containing high percentages of reactive solvents. The use of lower content by volume or less reactive exempt solvents, or the use of water bases offers the potential for greatly reduced ROG emissions from this source category. Each of these technologies is currently in use to some degree, and further product improvements should arise with evolving technology, increasing marketplace needs, and implementation of more stringent compliance requirements.

Chlorinated Solvent Based Coatings

Coatings in this category are those that are formulated with less photochemically reactive exempt solvent bases containing chlorinated and/or fluorinated hydrocarbons such as 1,1,1 trichloroethane, methylene chloride or trifluoromethane. The use of exempt solvent bases is expected to increase steadily as coating VOC limits become more stringent, and could result in ROG emission reductions of up to 100 percent. Chlorinated solvent-based coatings can be used with most conventional application equipment and have proven to be an acceptable alternative to high solvent coatings in areas such as metal parts and products coating. Solvent-based coatings offer several advantages such as durability, fast drying time, low corrosivity to the substrate, and a high gloss finish (DOHS, 1986). Disadvantages of the chlorinated solvent-based coatings include emission of potentially toxic compounds; worker exposure hazards; flammibility; and problems associated with waste management, disposal and liability (DOHS, 1986). Chlorinated solvent based coatings are viewed by some in the coating industry as " an intermediate solution " or an " interim step " to the future elimination of ROG emissions (Products Finishing Staff, 1986). Further research into the environmental and human toxicity effects of exempt solvent emissions is required to fully determine the impacts of these emissions.

High Solids/Low Solvent Coatings

High solids coatings contain greater than 75 percent solids by volume and represent one of the fastest growing technological areas of the coating industry. Recent technical advances in high solids coating systems have improved product performance quality, reduced emissions and eased application problems such as nonuniform film thickness and sagging (Welp, 1986.). Other advances which offer future success for high solids formulations include: (1) the availability of amino resins which have higher solids with lower viscosities, and cure faster and emit less free formaldehyde; (2) the successful development of additives which can act to control flow, act as curing catalysts, and reduce surface defects; (3) the continued development of new application equipment, such as electrostatic spraying which can improve transfer efficiency and results in a more uniform film thickness and less waste, and rotary paint flow applicators which are able to

apply coatings of higher viscosity (Welp, 1986). High solids coatings are presently widely used in the appliance coating industry and can offer high quality finishes with excellent transfer efficiencies and reduced VOC's in other coating categories as well (Products Finishing Staff, 1986). Long range emission reductions of as high as 15 to 45 percent may be realized as compared to higher solvent coatings with solids content in the range of 30 to 60 percent. High solids technology can result in increased solid waste disposal as overspray sludge in water pan booths after spraying is greater than with lower solids coatings.

Water-borne Coatings

In water-borne coatings, the photochemically reactive solvent base has been replaced by a water base of up to 80 percent (DOHS, 1986). This formulation not only affords a substantial reduction in ROG emissions as compared to solvent-borne formulations, but decreases worker exposure to potentially hazardous solvent compounds as well. Although coating product costs are lower, application costs for water-borne coatings are reported to be higher than those for conventional solvent-borne applications. However, plant line speed and production rates may be equivalent to high solvent coating processes once initial adjustments for the new coatings are made (Uhrmacher, 1987). The wood furniture industry, the largest user of solvents in the market segments that cover industrial coatings, has met some success in the use of water-borne coatings on many products such as chairs, coat racks, picture frames, wicker furniture, and other wood components. However, for application on fine wood furniture, several product suitability problems must first be resolved. Water-based coating formulations hold the market share in interior architectural coatings (DOHS, 1986) and are also growing in use in the coating of beer and soft drink cans and as primer coats by manufacturers of machinery and equipment. Development of a successful water-borne topcoat for use in metal coating processes would encourage future widespread use of this lower ROG-emitting coating technology. Water-borne coatings still must overcome some product suitability problems, but there is growing optimism that these problems are being solved and that usage of water-bornes will increase (Products Finishing Staff, 1986). Potential ROG emission reductions for full implementation of a control measure requiring water-based coatings could be in the range of 60 to 80 percent, based on the amount of solvent replacement.

High Performance Coatings

High performance coatings are those which may not necessarily be lower in VOC than conventional coatings, but will provide a more durable finish. Emission reductions are not actually realized through the use of the high performance coatings, but as a result of their extended performance characteristics. The enhanced coating performance results in less stripping and rework coating, thus emitting less ROG's. Coatings of this type are expected to grow in use in the aerospace and marine vessel coating industries.

VII. BANNING

In the event that products or processes are unable to switch to alternative non-solvent based technology, or use products reformulated with exempt or low VOC solvent bases, these products or processes will then be banned from use in the South Coast Air Basin.

COATING EMISSION CATEGORY

This ROG emission category is composed of architectural and industrial coating and graphic arts printing. The following section consists of a brief description of the sources within this category, as well as an estimate of ROG emission reductions achievable through application of the four Tier III control approaches.

Architectural Coatings

Architectural coatings are applied to stationary structures, mobile homes, streets and curbs. This category of coatings is currently regulated under District Rule 1113. The rule specifies the allowable solvent content (after thinning) for architectural coatings based on the specific type of formulation and the end use. The rule is specifically directed at coatings sold for use within the District. Exemptions for certain specialty coatings are included in the rule as is an exemption for coatings sold in containers of less than one liter.

Coatings for architectural use fall into 3 major categories: oil-based, water-based, and solvent-based. 2007 ROG emissions from oil based coatings are projected at 36 tons per day, while emissions for water based and solvent based are projected at about 8 and 5 tons per day, respectively. The combined ROG emissions from all three types of coatings are about 50 tons per day.

Control Approach I

The first control approach involves the implementation of alternative non-solvent-based methods or processes capable of eliminating ROG emissions. The use of powder, aqueous powder, or radiation curable coatings appears feasible for panels, fixtures, or components which can be finished prior to building installation in new construction. Further research and development of alternative architectural coating methods is required for widespread implementation of this control approach. Under full implementation, this control approach could eliminate ROG emissions from architectural coating.

Control Approach II

The second control approach involves reformulation of each of the three types of architectural coatings with less photochemically reactive exempt solvent bases containing chlorinated and/or fluorinated hydrocarbons, such as 1,1,1 trichloroethane, methylene chloride or trifluoromethane. Investigation into the use of add-on controls, possibly in the form of enclosures or tents connected to a collection or solvent recovery device, is needed to prevent chlorinated solvent emissions from entering the atmosphere. The implementation of improved operating practices capable of eliminating fugitive chlorinated solvent emissions will also be required. Implementation of this control approach may result in ROG emission reductions as high as 99 percent.

Control Approach III

The third control approach is based on reformulation of architectural coatings with low solvent content by volume. Formulations similar to water-based coatings would be required for all architectural applications. As stated above in the exempt solvent reformulation approach, investigation into the use of add-on control devices, or other processes to eliminate process fugitive emissions, is needed. Without effective controls, ROG emissions may

escape into the atmosphere. Improved operational practices capable of eliminating process reactive solvent emissions will also be incorporated into this control approach. Full implementation of this control approach may result in year 2007 ROG emission reductions as high as 99 percent.

Control Approach IV

The fourth control approach requires banning of any architectural coating processes or products which can not implement alternative coating methods or reformulation strategies to eliminate ROG emissions from this category.

Source category emission reduction potential

The range of ROG reductions available from the implementation of one or more of the four control approaches in the architectural coatings category can be as high as 99 to 100 percent of year 2007 emissions, or about 49 to 50

Other Surface Coating Operations

This category encompasses emissions from all other surface coating operations. The coating operations are very diverse and include auto assembly and refinishing; can and coil coating; manufactured metal parts and products coating; paper, fabric and film coating; rubber, glass and plastic coating; wood furniture and wood flatstock coating; marine vessel and aerospace coating, and other unspecified industrial surface coating. The individual categories are combined for this study, as applicable control concepts and techniques are similar for the majority of the categories. The adaptation or transfer of successful ROG elimination technology between categories is needed to achieve the required ROG emission reductions from this source category. District Regulation 11 and Rule 442 define operating practices, restrict solvent content of coatings, and for a number of categories, set minimum transfer efficiency application requirements. Tier I and II control measures are more stringent extensions of current requirements, and push for lower VOC content coatings, increased transfer efficiency application, improved operating practices, and removal of exemptions for small sources. Year 2007 ROG emissions from industrial and other surface coating operations are projected at 194 tons per day.

Control Approach I

The first control approach involves the implementation of non-solvent-based alternative methods or processes to eliminate ROG emissions in industrial

and other surface coating operations. Alternative coating methods currently available include several types of radiation-curable coatings, powder, and aqueous powder coatings. Radiation-curable coating technology has been successfully implemented in areas of paper, fabric, and film coating; metal coating; wood flatstock coating; plastic coating; and adhesive operations. Further developments in product suitability for radiation-curable coating technology can lead to widespread industrial application of this alternative technology. Powder and aqueous powder solutions can also eliminate ROG emissions from industrial or other surface coating categories, and have been used successfully in auto assembly, and metal parts and products coating operations. Continued technological development in product quality and application techniques can make powder coating available for the entire metal parts and products coating category. Aqueous powder application is currently in the developmental stages, but offers the opportunity for quality finishing in the metal coating industry as well. The use of alternative non-solvent-based products or processes can eliminate ROG emissions from the industrial and other surface coating source category.

Control Approach II

The second control approach for elimination of ROG emissions from industrial and other surface coating operations is based on the reformulation of all products with exempt less photochemically reactive solvents, such as 1,1,1 trichloroethane, methylene chloride, or trifluoromethane to be used in conjunction with add-on control devices, such as afterburners, or solvent recovery systems. Coatings reformulated with exempt solvents are compatible with most conventional application equipment, and have proven to be an acceptable alternative to reactive solvent-based coatings in areas such as metal parts and products coating. Further product development can result in widespread use of exempt solvent reformulations in a variety of coating applications. The implementation of improved operating practices will also be required to aid in the elimination of ROG emissions from coating processes. The full implementation of this control approach could result in emission reductions as high as 99 percent.

Control Approach III

The third control approach involves reformulation of industrial or other surface coatings with low reactive solvent content by volume for those products unable to be successfully reformulated with exempt solvents. The low solvent coatings are required to be used in conjunction with add-on

control devices, such as afterburners or solvent recovery sytems. Improved operational practices would also be required. High solids/low solvent coatings have provided quality surface finishes in the appliance coating industry, and with further research and development of application systems and product suitability requirements, could gain widespread acceptance as alternatives to high solvent coatings in auto assembly and refinishing, and can and coil coating. Aerospace and marine vessel coating applications may also be suitable for low solvent reformulations. However, the current military specifications will require revision in order for the new low solvent formulations to be accepted for use. Research and development of efficient add-on controls for these coating processes is required, but presents some difficulty due to the large size of aerospace components or marine vessels. The full implementation of low solvent reformulation with add-on control devices could result in ROG emission reductions as high as 99 percent.

Control Approach IV

The fourth control approach is based on banning or elimination of all products or processes remaining which were unable to adopt alternative technologies or reformulated products. This control approach would result in a 100 percent reduction of year 2007 ROG emissions for the remaining noncomplying products.

Source category emission reduction potential

The range of ROG reductions available from the implementation of one or more of the four control approaches can be as high as 99 to 100 percent of year 2007 ROG emissions from this combined coating category, or about 192 to 194 tons per day.

Graphic Arts Printing Category

The graphics arts source category includes five principle printing processes: letterpress, lithography, flexography, gravure, and screen printing. Emission of ROG's occur during the printing of inks onto porous and non-porous surfaces. Currently, emissions from these operations are regulated by District Rule 1130. This rule requires the use of low solvent technology or control systems with at least 90 percent efficiency (95 percent for publication gravure). Variable averaging periods (greater than one day) are available for small sources. The proposed short-range control measure is to require daily compliance and record keeping for small sources and does not result in

additional ROG emissions reductions. Year 2007 ROG emissions are projected as about 4.5 tons per day.

Control Approach I

The first control approach involves the replacement of solvent-based graphic arts operations with alternative non-solvent coating methods. Radiation-curable inks and clear overcoats are currently being used in the graphic arts industry for film and paper coating. These coatings are able to provide fast low temperature curing with high finish quality. Further development of radiation-curable inks and coatings could make this non-ROG emitting coating technique available to a greater number of processes within the graphic arts industry. Full implementation of radiation-curable, or other alternative technology to all sources within the graphic arts category could result in elimination of ROG emissions from this source category.

Control Approach II

The second control approach involves the reformulation of all reactive solvent-based inks or coatings with non-reactive exempt solvent formulations. Use of exempt solvent products would require add-on control devices, such as afterburners or solvent recovery systems, as well as improved operational practices to eliminate fugitive emissions. Research and development of new coating products with similar or improved performance characteristics is needed before industry-wide implementation can occur. Application of this control approach to all sources within the graphic arts category could result in elimination of up to 99 percent of year 2007 ROG emissions, or about 4.4 tons per day.

Control Approach III

Reformulation of ROG-based inks and coatings with low solvent content by volume is the third control option available for application to the graphic arts category. The use of low solvent products would require add-on control devices, and improved operating practices to eliminate process fugitive emissions. Current District rules require low-solvent technology for graphic arts processes, which may serve as an impetus for development of inks and

coatings with even lower solvent content by the year 2007. Full implementation of this control option for the graphic arts category could result in year 2007 emission reduction as high as 99 percent, or about 4.4 tons per day.

Control Approach IV

The fourth control approach is based on banning or elimination of all products or processes remaining which were unable to adopt alternative technologies or reformulated products. This control approach would result in a 100 percent reduction of year 2007 ROG emissions for the remaining noncomplying products.

Source category emission reduction potential

The range of ROG reductions available from the implementation of one or more of the four control approaches to the graphic arts category may be as high as 99 to 100 percent of year 2007 ROG emissions, or about 4.4 to 4.5 tons per day.

Total Emission Reduction Potential from Coating Operations

The emission reduction potential realized from complete implementation of one or more the four Tier III control approaches to the architectural and other surface coating, and graphic arts categories can be as high as 99 to 100 percent of year 2007 ROG emissions from these sources, or about 245 to 248 tons per day.

Direct Solvent Application

The following section presents the control elements as applicable to the direct solvent use category. There are several Tier III control options available for reducing emissions from solvent-based cleaning of parts and equipment, and for clean-up in coating operations. These control stategies are based on further technical development of Tier I and II control measures projected for ROG emission reductions in this source category, which include limited use of solvents based on the level of photochemical reactivity, use of add on control systems, use of low vapor pressure solvents or water-based

clean-up formulations, specific equipment and operating practices, and removal of exemptions for small sources. A large percentage of direct solvent application in the South Coast Air Basin is related to clean-up of coating operations. In instances where alternative non-solvent based coating methods are adopted, the need for solvent-based clean-up is eliminated. Processes which have opted for reformulation of coating products with non-reactive exempt, or low VOC solvents will use similarly based clean-up products, further reducing ROG emissions from coating clean-up or surface preparation operations. Banning of the remaining processes unable to implement low or non-solvent technolgy would result in elimination of related solvent-based clean-up procedures. Tier III control measures are based on the complete implementation of all applicable strategies to the highest degree in each of the direct solvent use source categories. Further administrative and technological development is required before these measures can be fully applied.

I. OPERATING PRACTICES

A wide range of operating practices can be utilized to reduce the use and emissions of solvents in cases where solvent-based cleaning is necessary. Increased employee awareness, as well as proper storage and handling of solvents and cleaning fluids, can result in reduced evaporative solvent emissions. The implementation of inspection and maintenance programs for solvent cleaning and degreasing operations can result in less evaporative loss of solvent and lower consumption. Inspection and maintenance programs of coating lines can also result in reduced ROG emissions and decreased need for solvent clean-up of the equipment.

An additional example of a procedure which would eliminate the need for solvent or water cleaning of a spray booth or other paint operation is to cover the walls, ceiling and floors of the booth with a contact film or paper liner which can then be stripped off of the booth and disposed of at the proper waste facility (DOHS, 1986a). Another option available for spray booths is to electrostatically ground the booth (DOHS, 1986a). This procedure will minimize the amount of overspray leaving the booth.

Outreach and education programs developed by the District and other local and state agencies can assure that cost effective alternatives to "business as usual" are presented to the operations currently using solvent-based cleaning. The full implementation of alternative non-solvent based cleaning and surface preparation techniques would be emphasized, followed by the use of non-reactive exempt solvent, and low solvent content by volume methods.

II. ALTERNATIVE CLEANING METHODS

For specific kinds of coatings and parts cleaning operations, alternative clean-up methods are available. These methods are currently being used and are expected to see increased use due to restrictions on the disposal of solvent waste and through other regulatory requirements, such as District rule changes. Among the methods available to limit or eliminate the requirement for solvent-based cleaning systems are the following alternatives and applications.

Water soluble cutting fluids can be used for machining parts and would reduce the requirement for solvent degreasing of these parts.

Peel coatings can be used in the place of protective oil coatings. These coatings are used for the protection of metal parts during transport and storage. Replacement of an oil coating with a peel coating would eliminate the need for degreasing the part before use.

Aqueous cleaning solutions (e.g. caustic and detergent) are a viable alternative for specific parts cleaning and coating clean-up applications. For parts cleaning, compatibility of the existing equipment and/or parts with the aqueous cleaning solution has to be verified before the solution is used. Aqueous spray or dip cleaning as a replacement for the equivalent solvent system would eliminate ROG emissions and result in a more manageable waste treatment/disposal problem. Cost for aqueous cleaners are about the same as for solvents, but treatment and disposal costs are expected to be lower (DOHS, 1986a).

Non-solvent based paint stripping can be substituted for solvent stripping methods. Among the alternatives available are: aqueous stripping solutions, abrasive stripping (sand or plastic bead blasting),

cryogenic stripping, thermal stripping, and molten salt stripping. A typical aqueous stripping system would be a caustic bath at about 200 oF. Caustic cleaning systems can be used for coatings based on alkyl resins, cellulosics, and on oil paints and phenolic/gum varnishes (DOHS, 1986a). High pressure alkali cleaning systems using wands or nozzles are also available. Plastic bead blasting is being used by domestic airlines and the U.S. Air Force to remove paint from aircraft (DOHS, 1986a). Portable equipment is available and advantages include the elimination of solvent wastes and reduced costs for raw materials and disposal. Cryogenic stripping utilizes liquid nitrogen in combination with plastic bead blasting to remove paint from a substrate. Molten salt baths for paint stripping are expensive but are very effective for removing epoxy and silicon coatings (DOHS, 1986a). Thermal stripping can be accomplished by heating with hot air, by torch, or by flame (DOHS, 1986a; and Whelan, 1986).

III. TRANSFER EFFICIENCY

In processes where exempt or low-solvent coatings products are used, the need for solvent clean-up can be greatly reduced through the use of increased transfer efficiency coating application methods. The use of higher transfer efficiency application equipment such as airless air-assisted, or electrostatic paint spray guns, or the use of automated or robotic coating processes results in less overspray or wasted paint material in work areas, and requires less solvent clean-up.

IV. PROCESS MODIFICATIONS

One method by which to decrease the need for clean-up solvents is to have a coating operation which either does not require or minimizes the requirement for, solvent cleaning. There are many alternative coating technologies in use today. These "solventless" coating systems are projected to see increased use due to advances in the technology, improved quality, crossover into additional areas of application and increased cost incentives for finishers.

Changes in processes or methods in the coating industry can reduce or eliminate the need for clean-up solvents. Powder coatings are applied as a dry powder so that overspray and spilled powder would not require clean-up with solvents. Ultraviolet (UV) and electron beam (EB) cured coatings utilize a reactive diluent which cures when illuminated with the appropriate wavelength of electromagnetic radiation. Overspray and spills of UV/EB radiation-cured coatings can be cleaned more easily than many conventional paints because the wasted paint will not have formed a dry film due to curing (DOHS, 1986a). Many waterborne formulations can also be relatively easily cleaned before curing without the extensive use of solvents (DOHS, 1986a).

V. ADD-ON CONTROL DEVICES

Add-on control systems for capturing and/or incineration of ROG's can reduce ROG emissions from solvent cleaning and surface preparation operations by up to 99 percent. Carbon adsorption systems are able to capture a high percentage of the solvent in the process waste gas stream. The captured solvent may then be desorbed from the carbon bed and recovered for reuse or disposal. Incineration units destroy the solvent-laden waste gas stream through high temperature oxidation, and may employ heat recovery devices. Wet scrubbers with closed-loop vapor recovery systems have also been successfully employed to capture solvent vapors.

VI. REFORMULATION

Reformulation of solvent blends used for coating and surface clean-up or parts cleaning is defined, for this report, as replacement of reactive solvents with non-reactive (exempt or "compliance") solvents or, replacement with low solvent content by volume. A wide variety of formulations are available for surface cleaning. These formulations can include reactive and non-reactive components in various proportions. Requiring an increase in the percentage of non-reactive exempt solvents or a total replacement of the reactive compounds in formulations used for surface cleaning is a straightforward means of lowering solvent emissions. Tier I and II control measures for reducing ROG emissions from the use of clean-up solvents proposes a

requirement for reformulation with lower vapor pressure or exempt solvent compounds. The Tier III control measurers for this category are an extension of this strategy.

In some cases, the replacement compounds having the lower vapor pressure also happen to be non-reactive with respect to formation of ozone (Price, 1987). Paint stripper and equipment cleaning formulations in particular can be largely based on methylene chloride (Price, 1987). Other compounds utilized in the formulation of paint strippers and surface cleaners include isopropyl alcohol, toluene, methyl ethyl ketone, various chlorfluorocarbons, amines and amides, phenols, and 1,1,1 trichloroethane. The volume percent of non-reactive solvent in these formulations can vary from zero to 90 percent (Price, 1987; and Hahn and Werschulz, 1986). Paint strippers are formulated to take advantage of the properties of the component solvents, low pH, and in some cases, elevated temperatures. As there are such a great number of formulations on the market for paint strippers and surface cleaning solvents, reformulation of these compounds should serve to reduce ROG emissions. In the next 10 to 20 years, manufacturers of these products should be able to develop formulations that minimize and eventually, totally eliminate the use of ROG solvents.

Parts cleaning by utilizing reactive solvents (e.g. stoddard solvent) for tank cold cleaning operations in small tanks can easily be switched to non-reactive solvents in cases where solventless cleaning systems cannot be utilized. Among the alternative exempt solvents available are perchlorethylene, methylene chloride, freons and 1,1,1 trichloroethane.

One method of reducing potential emissions of ROG and halogenated solvents, while also reducing solvent contamination of waste water, is to use solvent and water formulations. For example, various paint strippers were tested by U. S. Environmental Protection Agency scientists for the purpose of determining their effectiveness relative to the toxicity of the wastewater generated from the process. Two solvent and water formulations, one a 1:1 mix of a product with water, were as effective as the solvent strippers for removing typical paint types (Hahn and Werschulz, 1986). Water and solvent formulations may not be applicable for all situations (e.g. in situations where corrosion is critical), but they can be as effective as ROG solvent based formulaes, and at the same time can reduce potential emissions of halogenated solvents.

Rules requiring reformulation with exempt or low VOC solvents and add-on controls would reduce year 2007 ROG emissions from cold tank parts cleaning, surface cleaning, equipment cleaning, and coating process clean-up by as much as 99 to 100 percent. Several alternatives to reactive solvent-based cleaning and surface preparation methods are currently available, and research and development of additional formulations is expected within the next 20 years. The judicious application of these alternative methods will also minimize the generation of hazardous wastes, contaminated wastewater, and air emissions of halogenated compounds.

VII. BANNING

In the event that products or processes are unable to switch to alternative non-solvent based technology, or use products reformulated with exempt or low VOC (volatile organic content) solvent bases, these products or processes will then be banned from use in the South Coast Air Basin.

DIRECT SOLVENT USE EMISSION CATEGORIES

This section discusses the application of the four control approaches; alternative methods; exempt solvent reformulation in combination with add-on controls; low reactive solvent content by volume, also in combination with add-on control devices and; banning of processes or products unable to eliminate ROG emissions. Estimated emission reductions are included and are based on year 2007 emission projections.

Industrial Solvent Use for Cleanup and Surface Preparation

Solvent-based cleaning of equipment, spray booths, and other materials used in surface coating operations is currently regulated under District Rule 442. This rule limits emissions of solvents on the basis of their degree of photochemical reactivity. The rule requires a control efficiency of 85 percent if these specific solvent-based limitations are not used. The Tier I and II

control measures for this source of ROG emissions requires that low vapor pressure solvent or water based clean-up formulations be used. Year 2007 ROG emissions from this category are projected at about 22 tons per day.

Control Approach I

The first control approach is based on the adoption of alternative non-solvent based cleaning or surface preparation methods or processes. Several non-solvent based methods currently exist for coating and part cleaning, such as aqueous cleaning solutions, and the use of water soluble cutting fluids and peel coatings for parts. Alternatives available for non-solvent-based paint stripping currently in use include aqueous stripping, abrasive stripping, and thermal stripping. Further research and development of non-solvent based cleaning and surface preparation products or processes is needed for industry-wide implementation of this control approach. Complete implementation of alternative methods in the clean-up and surface preparation category would result in the elimination of year 2007 ROG emissions in this category.

Control Approach II

The second control approach applied to the solvent clean-up and surface preparation category involves the reformulation of reactive solvent products with non reactive exempt solvents, such as 1,1,1 trichloroethane, methylene chloride, or trifluoromethane. These formulations are to be used in conjunction with add-on controls and improved operating practices in order to eliminate process fugitive emissions. Formulations containing exempt solvents are currently in use for paint stripping and equipment cleaning results. Paint strippers reformulated with exempt solvent, or exempt solvent in combination with water, are also effective for removing typical paint types. Further research is needed in this ROG emission category to determine effective product formulations and applications for the diverse number of processes involved. Full implementation of this control approach can result in ROG emission reductions in the industrial solvent use category for clean-up and surface preparation as high as 99 percent, or about 21 tons per day.

Control Approach III

The third control approach is based on reformulation with low reactive solvent content by volume for those products or processes unable to utilize exempt solvent reformulation technology. The reformulated products will be

used with add-on control devices, and improved operating practices in order to eliminate process fugitive emissions. A number of coating clean-up and surface preparation processes have been able to successfully implement low solvent cleaning agents. Further development of low solvent formulations and applications can provide for technology crossover, and widespread use of this low ROG-emitting technology. Emission reductions realized through full implementation of this control approach can be as high as 99 percent of year 2007 ROG emissions, or about 21 tons per day.

Control Approach IV

The fourth control approach is based on banning or elimination of all clean-up or surface preparation products or processes remaining which were unable to adopt alternative technologies or reformulated products. This control approach would result in a 100 percent reduction of year 2007 ROG emissions for the remaining noncomplying products.

Source category emission reduction potential

The emission reductions available from the implementation of one or more of the four control approaches is in the range of 99 to 100 percent of year 2007 ROG emissions projected for solvent use in clean-up and surface preparation categories, or about 21 to 22 tons per day.

Solvent Cleaning and Degreasing Tanks

This source category includes two major types of degreasing systems, each with variations in operating procedures. These parts cleaning/degreasing tanks may either use a cold solvent, typically petroleum based (stoddard solvent), or a a heated solvent, normally a halogenated hydrocarbon. The heated solvent tanks produce a vapor above the liquid, which is where the parts are cleaned (vapor degreasing). Parts may be dipped into a degreasing tank or they may be run through the tank on a conveyor system. These sources are regulated under Rule 1122 which establishes equipment design and operating requirements. Tier I and II control measures for this category specify further operating and equipment requirements, add-on controls, and

removal of the exemption for small sources. Also, an outreach program developed with the state Department of Health Services, local sanitation districts and other local government is proposed to improve operator awareness and skills. Year 2007 ROG emissions for solvent leaning and degreasing are projected at about 36 tons per day.

Control Approach I

The first control approach involves the implementation of alternative non-solvent based methods for solvent cleaning and degreasing tanks. Several processes can be employed to eliminate the need for part degreasing, such as replacing petroleum based products used during part machining with water soluble cutting fluids, as well as replacement of oil as a protective part coat with peel coatings. Additional research and development of alternative cleaning and degreasing systems is needed. Complete implementation of non-solvent based cleaning and degreasing methods could result in elimination of ROG emissions from this category.

Control Approach II

The second control approach requires the reformulation of reactive solvent products used in solvent cleaning and degreasing tanks with non-reactive exempt solvents. The reformulated products will be used in conjunction with add-on control devices. Improved operating practices will be required, including the use of equipment inspection and maintenance programs, to assure adequate freeboard ratio is maintained, and that tank covers or conveyor system are operational, as well as controlling solvent leaks or other sources of fugitive emissions. Exempt solvents such as perchloroethylene and methylene chloride have been used successfully in several metal parts cleaning operations, and offer the possibility for technology crossover into other cleaning and degreasing operations. Further technological advancement is required to assure development of compatible exempt solvent cleaning and degreasing compounds for industry-wide use. Full implementation of this control approach can result in reduction of year 2007 ROG emissions by as much as 99 percent, or about 35 tons per day.

Control Approach III

The third control approach is based on reformulation with low reactive solvent content by volume for those products or processes unable to utilize exempt solvent reformulation technology. The reformulated products will be

required to be used in conjunction with add-on controls and improved operating practices to eliminate process fugitive emissions. Research and development of low solvent by volume content cleaning or degreasing agents compatible with a wide variety of applications is needed to achieve implementation of this control approach. Full implementation of reformulated low solvent products can result in emission reductions as high as 99 percent, or about 35 tons per day.

Control Approach IV

The fourth control approach is based on banning or elimination of all products or processes remaining which were unable to adopt alternative technologies or reformulated products. This control approach would result in a 100 percent reduction of year 2007 ROG emissions for the remaining noncomplying products.

Source category emission reduction potential

The range of reductions available from the implementation of one or more of the four control approaches is in the range of 99 to 100 percent of year 2007 ROG emissions from solvent cleaning and degreasing, or about 35 to 36 tons per day.

Dry Cleaning

There are currently two types of dry cleaning systems in use in the District, perchloroethylene (Perc) dry cleaning and petroleum solvent drycleaning. Both types of operations are currently regulated under District Rule 1102.1 which specifies equipment design and operating requirements. The Tier I and II control measures proposed for perchloroethylene dry cleaning specify equipment and operating practices, and removal of the exemption for small sources. Year 2007 emissions are projected at about 26 ton per day.

There are two types of perchloroethylene dry cleaning systems. In the first system, washing and spinning is done in one machine and then the articles of clothing are transferred manually to the dryer. In the second system,

garments are taken through the whole cycle of wash, spin and dry in one machine, which eliminates emissions from the transfer operation. This system is called dry-to-dry. Facilities within the District using more than 320 gallons of perchloroethylene are required to vent all exhausts from cleaning equipment and floor pickups to a control system. Tier I and II control measures specify equipment and operating practices.

The petroleum solvent dry cleaning operations in the District use a process similar to ordinary laundering in water and to perchloroethylene dry cleaning. Emissions occur during wash, spin and dry cycles as well as during transferring between washing and drying machines, and from dryer to storage areas. District Rule 1102.1 specifies operating requirements for these types of systems, and requires add-on controls for facilities using more than 2.642 gallons per year of petroleum solvent. Proposed Tier I and II measures proposed include additional operating requirements and lowering of the exemption limit to 760 gallons of solvent per year. ROG emissions projected for the year 2007 from petroleum dry cleaning are about 1 ton per day.

Control Approach I

The first control approach involves the adoption of alternative non-solvent based dry cleaning methods. The use of alternative methods applied to petroleum solvent-based systems entails switching to perchloroethylene solvent, and can result in the elimination of 2007 emissions from petroleum-based dry cleaning or about 1 ton per day. Perchloroethylene is considered as an exempt solvent of low reactivity, however the use of completely non-reactive cleaning agents could result in the elimination of ROG emissions from perchloroethylene dry cleaning.

Control Approach II

The second control approach calls for reformulation with non-reactive exempt solvents. Petroleum based dry cleaning, required to switch to the alternative non-solvent based method of perchloroethylene dry cleaning, is not considered separately for reformulation. The use of add-on controls and improved operating practices will be required in non-reactive exempt solvent dry cleaning processes to virtually eliminate fugitive chlorinated solvent emissions. The EPA is currently studying the reactivity and toxicity of perchloroethylene, and the findings may determine whether efforts will be taken to reformulate products composed of this compound, and to what extent it will be required. Reformulation with a totally non-reactive solvent

compound could eliminate ROG emissions from the dry cleaning process. The improvement of fugitive ROG control through detailed operating requirements for transfer of solvent-laden clothing between the washing and drying cycles to prevent fugitive emissions, as well as the use of an outreach program targeted at small operators emphasizing proper maintenance of the add-on control systems. Control of fugitive emissions could be further controlled by passing building exhaust through the clothes dryer and then into the add-on device. Full implementation of this control approach could result in emission reductions of up to 99 percent year 2007 emissions for the dry cleaning category, or about 25 tons per day.

Control Approach III

The third control approach is based on the use of products reformulated with low solvent content by volume. The reformulated products will be used in conjunction with add-on controls and improved operating practices to eliminate process fugitive emissions. This reformulation strategy may become necessary based on findings regarding the reactivity and toxicity of perchloroethylene. A stringent maximum solvent content restriction will be enacted by the District in order to minimize ROG emissions from this method of reformulation. Further study is needed to determine the need for reformulated products, as well as their subsequent development and application. The implementation of this control strategy to the dry cleaning category could reduce year 2007 ROG emissions by as much as 95 percent, or about 24 tons per day.

Control Approach IV

The fourth control approach is based on banning or elimination of all products or processes remaining which were unable to adopt alternative technologies or reformulated products as necessary. This control approach would result in a 100 percent reduction of year 2007 ROG emissions for the remaining noncomplying products.

Source category emission reduction potential

The range of ROG reductions available from the implementation of one or more of the four control approaches is in the range of 95 to 100 percent of year 2007 ROG emissions from dry cleaning or 24 to 26 tons per day.

Asphalt Paving

There are currently two types of asphalt paving methods available for use in the District. Both methods are regulated under District Rule 1108 which specifies volatile content and maximum evaporation rates for solvents and emulsifying agents. The first method, cutback asphalt paving, involves the liquification of asphaltic cement by mixing it with a solvent based distillate. Different distillates can be used depending on the desired rate of cure of the asphalt once it is applied to the road surface. Gasoline is the distillate associated with rapid cure, kerosene is associated with medium cure, and fuel oil with slow curing. This method is highest in ROG emissions as VOC's escape during the mixing of the asphalt and as the distillate volatilizes from the asphaltic base after application to the surface.

Emulsified asphalt paving is the second method and differs from cutback asphalt in the fact that asphaltic cement is mixed with water and a low ROG content emulsifying agent rather than a solvent based distillate. This type of asphalt is also classified as rapid, medium or slow curing. ROG emissions are reduced in this paving method ROG emissions occur during mixing, application and curing of the pavement. Year 2007 ROG emissions for asphalt paving are estimated at about 5 tons per day..

Control Approach I

The first control approach involves the adoption of alternative non-solvent based asphalt paving methods. Alternative methods would involve the switching of cutback asphalt systems to lower ROG-emitting emulsified asphalt operations. Further study is required to identify and develop alternative methods for emulsified asphalt paving. Complete implementation of alternative non-solvent based methods can result in the elimination of year 2007 ROG emissions in the asphalt paving category.

Control Approach II

The second control approach involves reformulation of both types of asphalt paving mixtures with exempt or non reactive compounds. Further study is required to determine the most effective formulations and appropriate methods to eliminate process fugitive chlorinated solvent emissions during

mixing and curing of the asphalt. Full implementation of this control strategy in the asphalt paving category could result in ROG emission reductions as high as 99 percent, or over 4 tons per day.

Control Approach III

The third control approach is based on the reformulation of emulsified asphalt pavement mixtures with low solvent content by volume compounds. Further research is required in the development of asphalt mixturers utilizing lower ROG content compounds. Attention must be given to California Department of Transportation guidelines when new mixtures are developed. The development of control techniques to eliminate fugitive process emissions also requires further research. Complete implementation of this control measure could result in ROG emission reductions in asphalt paving emissions for the year 2007 as high as 99 percent, or over 4 tons per day.

Control Approach IV

The fourth control approach is based on banning or elimination of all products or processes remaining which were unable to adopt alternative technologies or reformulated products. This control approach would result in a 100 percent reduction of year 2007 ROG emissions for the remaining noncomplying products.

Source category emission reduction potential

The range of ROG reductions available from the implementation of one or more of the four control approaches is in the range of 99 to 100 percent of year 2007 ROG emissions from the asphalt paving category or about 4 to 5 tons per day.

<u>Total Emission Reduction for Direct Solvent Use Categories</u>

The total emission reductions available after full implementation of one or more of the four Tier III control approaches to the sources within the direct solvent use category can be as high as 99 to 100 percent of year 2007 ROG emissions or about 83 to 88 tons per day.

Consumer Products

A wide variety of products used in households, institutions and commercial establishments contain organic compounds which, when released into the atmosphere, can react to form ozone and other photochemically reactive pollutants. Products such as paints, insecticides, cleaning solutions and automotive and personal care products contain and release reactive organic gases during use and disposal. The photochemically reactive organic compounds in these products serve as either part of the formulation of the product itself, such as in solvent cleansers, or to propel the product, such as in aerosol spray products. The emissions from these products represent a substantial portion of the ROG emissions from solvent use in the South Coast Air Basin. Emissions from these products are projected to increase substantially over the next 20 years as the region's population increases, with year 2007 emissions projected at 129 tons per day.

Domestic products with the exception of those rules covering the ROG content of architectural coatings and the ban on chlorofluorocarbons in aerosol products, are not currently regulated by the District. Tier I and II control measures have proposed reduction of ROG emissions from this source category through the use of less polluting mechanisms to propel the products and/or reformulation with less reactive components. The Tier III control measures are an extension of the Tier I and II controls aimed at eliminating reactive solvent emissions from the consumer products category.

I. Alternative Application and Propellant Mechanisms

The use of alternative application methods in conjunction with reformulation efforts can act to substantially reduce ROG emissions from aerosol spray products. Mechanical dispensers such as pumps, sprays and squeeze bottles, which offer a higher transfer efficiency application, without using photochemically reactive organic compounds, or alternatively pressurized devices such as the self-generating carbon dioxide spray, could also be used to dispense aerosol products. Underarm products are currently one commercial product area where the California Air Resources Board (ARB) and the District are considering implementing control measures to help reduce ROG emissions. Efforts in the areas of reformulation and alternative dispensing mechanisms for this product line have thus far resulted in the formulation of lower ROG-emitting products, as well as the widespread use of several higher transfer efficiency application methods, including roll-ons and stick solid deodorants and antiperspirants.

II. Solvent Reformulation

The reformulation of highly reactive solvent-based consumer products could act to substantially reduce future ROG emissions. Reformulation efforts would involve the replacement of the solvent bases with less reactive exempt solvents, such as 1,1,1 trichloroethane and methylene chloride, water bases, or water and solvent in varying proportions. Although the possibility for reformulation of a stable product alternative may exist, the end use of the product must be taken into account to determine the best method of reformulation. For example, hair spray and deodorant are normally solvent-based for quick drying on surface contact. A much slower drying time would result were the products water-based; hence, consumers may reject the product. On the other hand, products such as liquid soaps and detergents not concerned with drying time could be successfully water-based while maintaining performance characteristics (Present, 1987). Formulators may achieve varying degrees of success as the range of commercial products is very wide and some products may not be compatible with exempt solvent or water-base requirements.

III. Banning

In the event that products or processes are unable to switch to alternative non-solvent based technology, or use products reformulated with exempt or low VOC content bases, these products or processes will then be banned from use in the South Coast Air Basin.

Consumer products emission category

The main emphasis of ROG reduction in the consumer products emission category is the use of alternative non-reactive propellant mechanisms, and the reformulation of reactive solvent-based carriers in products. The consumer products category encompasses a wide range of commercially available products from personal care products, such as aerosol deodorants and hairsprays to highly reactive cleaning solutions,paints, strippers, and solvents. Year 2007 ROG emissions from the consumer products category are projected at about 129 tons per day.

Control Approach I

The first control approach requires alternative methods, products, or processes to eliminate reactive solvent emissions in the consumer products category. Elimination of reactive aerosol propellants, and the development of alternatively pressurized devices, such as the self-generating carbon dioxide spray is one alternative method by which to achieve ROG reductions in the consumer products category. Other alternative applications include the use of mechanical dispensers such as pumps, sprays, or squeeze bottles. Further research and development of alternative application methods and non-reactive propellants is needed for complete implementation of this control technique. This strategy can result in a 100 percent reduction of ROG emissions from aerosol propellant consumer products, or about 23 tons per day.

Control Approach II

The second control approach would occur simultaneously with the reformulation of aerosol propellants or alternative application devices, and involves the reformulation of non- aerosol consumer products with less

photochemically reactive exempt solvent bases containing chlorinated and/or fluorinated hydrocarbons, such as 1,1,1 trichloroethane, methylene chloride, or trifluoromethane. Further study is required to determine the scope of reformulation required, and the use of reactive solvent bases in regard to product compatibility and end use. Study may also be required regarding the use of chlorinated solvents in products for human application. The full implementation of this control approach, in conjunction with alternative propellant mechanisms, can result in ROG emission reductions as high as 99 percent or about 128 tons per day.

Control Approach III

The third control approach is based on reformulation of reactive solvent carriers with low solvent content by volume compounds. This control measure would also be implemented simultaneously with the use of alternative application methods, or non-reactive solvent propellants. Implementation of this control strategy is least favored for ROG elimination through reformultion, as low solvent formulations will result in fugitive ROG emissions entering the atmosphere. A stringent maximum solvent content restriction will be enacted by the District in order to minimize ROG emissions from this method of reformulation. Low solvent formulations, and low VOC solvents in combination with water, have been successfully developed for several products, including household painting products, soaps, and detergents. Further research and development of complying product formulations, and crossover of technology to other product categories is needed. Full implementation of this control approach, in conjunction with alternative non-solvent propellant mechanisms, can result in year 2007 emission reductions in the consumer products category as high as 95 percent, or about 123 tons per day.

Control Approach IV

The fourth control approach is based on banning or elimination of all products or processes remaining which were unable to adopt alternative technologies or reformulated products. This control approach would result in a 100 percent reduction of year 2007 ROG emissions for the remaining noncomplying products.

Total Emission Reduction for Consumer Product Category

The long range ROG reductions available from the implementation of the one or more of the four control approaches can achieve a 95 to 100 percent reduction in year 2007 emissions from aerosol and non aerosol consumer products or 123 to 129 tons per day.

CHAPTER 4

STRATEGIC PLAN

CHAPTER IV

STRATEGIC PLAN

In order to achieve the level of ROG emission reductions necessary to bring the South Coast Air Quality Management District into attainment with state and federal ozone standards by 2007, the control elements discussed have been incorporated into an aggressive strategic plan. The plan for ROG elimination is based on four control options which will be examined for application in the solvent use category, including: 1) implementation of alternative methods or processes utilizing non-solvent based products; 2) reformulation of reactive solvents, coatings, and consumer products with non-photochemically reactive exempt or compliance solvent-bases, to be used in conjunction with add-on controls; 3) the use of low reactive solvent content by volume formulations, also to be used in conjunction with add-on controls and; 4) banning of all products or processes unable to implement the three previous control strategies.

The use of this four step control strategy assures that facilities unable to comply with the most favored control option, using alternative non-solvent based methods or processes, will then be required to use reformulated products in combination with add-on control devices. If reformulation is not a plausible option, the reactive solvent-based products or processes will not be permitted in the South Coast Air Basin.

The estimated degree of market penetration is based on the greatest extent of technological application of the specific control element to all sources within the solvent use emission category. The projected emission reductions are based on the maximum level of reduction achievable through the application of the particular control technique, and are based on year 2007 ROG emissions of 470 tons per day.

Alternative Methods and/or processes

The control option most favored for elimination of ROG reductions in the South Coast Air Basin is the use of alternative non-solvent-based application methods for coatings and consumer products, as well as the use of alternative non-solvent-based cleaning methods. The level of market penetration achievable in the solvent use category for adoption of alternative methods or processes is estimated at 60 percent due to the impetus of crossing over of alternative technologies to other source categories. The implementation of this control strategy will be able to completely eliminate ROG emissions in the portion of the market to which it is applied, resulting in a reduction of about 281 tons per day.

Exempt Solvent Reformulation

In processes where the implementation of non-solvent-based alternative methods are not feasible, the next control approach to be examined for application is reformulation with nonphotochemically reactive exempt solvents, such as 1,1,1 trichloroethane, methylene chloride, or trichlorotrifluroethane, to be used in conjunction with add-on control devices and improved operating practices. These solvents are favored for use in regard to ozone formation, but uncertainty remains as to the level of toxicity or possible carcinogenicity of the compounds. The level of penetration achievable in the solvent use category for exempt solvent reformulation is estimated at 80 percent of the remaining market. The implementation of this control strategy will be able to reduce emissions by as much as 99 percent in the portion of the market to which it is applied, or reduction in ROG emissions of 150 tons per day.

Low Solvent Reformulation

In cases where switching to alternative processes or methods, or using exempt solvent reformulated products is not feasible, reformulation of products with reactive low- solvent content by volume compounds may be used in conjunction with add-on control devices, and improved operating practices. This control strategy is not favored in regard to ozone formation, but may limit emission of air toxic compounds. Penetration of 80 percent of the remaining market is estimated with emission reductions projected at 99 percent or 30 tons per day.

Banning of ROG Products

Remaining processes or products unable to implement alternative methods or processes, or the use of exempt or low solvent reformulations will be banned from use. In light of the reductions achieved through full implementation of the other control strategies, remaining emissions comprise less than five percent of the total ROG emissions predicted for the year 2007 and could be eliminated by the application of this control strategy.

ACTIONS TO FACILITATE IMPLEMENTATION

In order to facilitate the complete implementation of this multi-step strategic plan, the following actions are recommended.

Establishment of a cooperative effort between the District, product manufacturers, and end users to fully assess the constraints involved with complete implementation of the strategic plan.

Development of an outreach program aimed at disseminating information and educating solvent use business owners and operators, and the public that alternative technologies, and reformulated low or exempt solvent products can be successfully substituted for reactive solvent processes or products.

Research aimed at investigating the wide variety of products requiring reformulation, and consideration of the application and end uses for new product compatibility and performance

Examination of the potential for successful crossover of control technology into other source categories.

Revision of military coating specifications to accomodate low or exempt solvent coating technology.

Development of legislative policy, such as tax incentives or emission credits, to encourage or enhance the timely adoption of new technologies by industry.

Examination of processes or product lines unable to implement the alternative processes or reformulation control options, and determination of economic impact of banning these operations on industry, and the basin as a whole. Consideration may need to be given to exemptions or time extensions if control technology is not applicable.

Examination of the environmental effects associated with the implementation of the strategic control plans. Issues to be considered include toxic emissions, stratospheric ozone depletion, waste disposal problems, and cross media contamination.

IMPACTS OF CONTROL STRATEGY IMPLEMENTATION

The proposed Tier III strategies for reducing reactive organic gas emissions in the South Coast Air Basin are earmarked for full implementation within the next 10 to 20 years. These control measures must be evaluated in terms of future environmental, economic, energy consumption, and administrative impacts in order to fully determine the effectiveness and consequences associated with full implementation.

Environmental Impacts

The environmental impacts associated with the use of lower or non-reactive solvent-based cleaning agents, coating processes, or consumer products are, for the most part, positive. Substantial ROG emission reductions could be realized as the result of implementing the long range control measures in the solvent use categories, thus reducing the potential for ozone formation. Negative air quality impacts involve the potential increased emission of potentially toxic compounds as a result of the substitution of the exempt or "compliance" solvents (1,1,1 trichloroethane, methylene chloride and

trichlorotrifluoroethane) for more photochemically reactive solvent bases. The extent of toxicity of these substances is uncertain at this time, but the possibility of carcinogenicity has not been eliminated. Trichloroethane and methylene chloride may contribute to stratospheric ozone depletion. Another negative impact of this long range control strategy involves the possibility of increased emission of oxides of nitrogen as a result of high temperature combustion of volatile organic compounds in process afterburners or incinerators.

Several other environmental impacts are associated with the reduction of ROG's from solvent and coating use in the South Coast Air Basin. Positive effects of the reduction in use of reactive solvents includes generation of less waste solvent to dispose of which could be potentially hazardous or toxic, as well as the reduction of solvent-containing wastewater or runoff generated at facilities which when aerated could result in cross media-contamination. Another positive effect of requiring increased control of reactive solvents would be the implementation of widespread resource recovery for product reuse in its original form or as a lower grade product.

Economic Impacts

The economic impacts that accompany the implementation of long range control measures to reduce ROG emissions from coating and solvent use may affect manufacturers and finishers as well as consumers. Solvent and coating formulators will be required to develop and evaluate exempt solvent-based or non-solvent containing products to replace those containing highly photochemically reactive components. This research and development process may be very timely and cost intensive to product manufacturers and may be reflected in end user price.

Formula Changes for Solvents

The exempt or compliance solvents, methylene chloride and 1,1,1 trichlorethane, are more costly than conventional solvents, but because they are compatible with existing dry cleaning and degreasing systems, little additional capital investment is required for their sole use.

Formula Changes for Coatings

The use of powder and aqueous powder suspension coatings involves lower operating costs than the use of conventional solvent-borne coatings, while the application of waterborne and high solids formulations demand higher annual operating costs (Cole, 1984). The costs may be attributed to the difficulty of application and coating performance characteristics of water borne and high solids coatings. Coating systems utilizing ultraviolet radiation curing were found to have lower operating costs than either electron beam curing or conventional thermal curing operations It is important to remember that, as the cost of petroleum rises on the world market, the use of alternative formulations could become even more attractive economically than conventional petroleum distillate based products.

Coating Process Changes

Product finishers may be required to refit or retool coating lines if existing application equipment is not compatible with the new lower ROG-emitting coating products or improved application methods. The refitting may be as simple as replacement of conventional air spray guns with those of higher transfer efficiency such as air-assisted airless or electrostatic, or as extensive as retooling of the entire coating line for use of robotics or automated systems on large operations. Some finishers unable to adapt to coating formulations or processes because of high costs or product suitability problems may be forced into alternate technology development or out of the market altogether.

Energy Consumption Impacts

The greatest expenditure of energy during the coating process is related to ventilation air for the spraying areas and drying ovens. Through the use of formulations requiring less thermal drying, energy consumption can be greatly reduced. Those coatings formulated with the chlorinated solvents offer energy savings due to the high evaporative potential of 1,1,1 trichloroethane and methylene chloride, as some formulations may require only air drying instead of oven baking. Ultraviolet and electron beam cured coatings require no thermal curing and thus, offer substantial energy savings. High solids coatings are able to offer reduced energy consumption through the use of formulations containing a catalyzing component which acts to speed curing, and may be accomplished with a minimal amount of oven drying. Powder and aqueous powder suspensions require less energy consumption for curing than conventional solvent-borne coatings as less heat energy is required to fully polymerize or cure the coating. Water borne coatings have been found to require greater energy expenditure to achieve the desired finish as the coated surface has been found to remain tacky for extended periods following drying.

Energy consumption for the continued use of solvent-borne formulations can be lowered through process modifications involving the use of microprocessor controls to decrease the drying oven ventilation air flow while safely increasing the drying oven LEL (Lower Explosive Limit) concentration to near 50 percent. This acts not only to reduce energy consumption for ventilation air flow through the dryer, but allows for the delivery of a more concentrated stream of VOC-laden waste gas to the afterburner which results in more efficient destruction and less consumption of auxiliary fuel.

The use of robotic or automated coating processes can also serve to reduce process energy consumption as large amounts of climatically controlled make-up air are not needed to ventilate the spray booth, as is the case when humans are spraying manually.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER V

CONCLUSIONS

Development of Tier III controls for reactive organic gas emissions will require technological advancement in a number of areas in the solvent use category, and are slated for full implementation within the next 10 to 20 years. Many of the proposed measures are extensions of Tier I and II controls which are capable of technology transfer to other source categories.

The overall goal of the Tier III strategies to eliminate ROG emissions can be achieved through the use of alternative non-solvent-based processes or methods in coating and solvent cleaning, and in place of reactive aerosol propellants and solvent carriers in consumer products. Reformulation of reactive solvents with non-reactive exempt, or low VOC solvents in conjunction with add-on controls and improved operating practices can eliminate up to 99 percent of ROG emissions from solvent use processes in the South Coast Air Basin. Any solvent-based products or processes remaining unable to implement either of the three control approaches will then be banned from use in the Basin. A series of control strategy implementation actions including District outreach and educational programs, development and advancement of technology, legislation, and environmental and economic impact analysis is required to assure complete and timely application of the control strategies necessary to eliminate ROG emissions.

RECOMMENDATIONS

It is recommended that the Tier III ROG control measures be further refined within the next 10 to 20 years, and incorporated into the Rules and Regulations of the South Coast Air Quality Management District, as the resulting emission reductions will act to bring the South Coast Air Basin into attainment with federal and state ozone standards. Development of a

cooperative effort between representatives of industry and the SCAQMD to examine the constraints and options available, as well as determination of technology advancements required is a logical starting point.

CHAPTER 6

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